ThinkCycle at M.I.T.

Sharing Distributed Design Knowledge for Open Collaborative Design

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Creating a Culture of Socially-Conscious Design Innovation

How does one go about designing better water filters for solving the clean water needs of 1.3 billion people, simplified intravenous (IV) treatment devices for cholera patients in refugee camps, low-cost prescription eye-wear for communities in Africa or active response kits and temporary shelters for disaster relief? Critical design challenges in the environment and under-privileged communities have generally not been well addressed by either existing market mechanisms, academia or government organizations. We feel that such initiatives require diverse domain expertise (from doctors, engineers and practitioners), motivated design teams (perhaps based in universities and industry), and field-experience from both entrepreneurial and non-governmental organizations (NGO) working in such areas. This class of "critical global challenges" requires a new approach towards collaborative design, one, which embraces multi-disciplinary teams and contributions from participants in different institutional settings.

In collaborative projects, the emerging design knowledge and process is rarely captured and shared among others. In the *open source* community, it has been argued that in many cases it is beneficial for the ongoing design to be exposed to public peer review and contributions from a wider community of experts. Ideally, such a process would lead to more rapid and innovative design iteration. Why is collaborative design around critical challenges not approached in this manner today? Is it because of inappropriate design tools or a lack of social awareness and political will on the part of organizations and institutions? We believe there is a genuine need both for designing novel collaborative tools and creating a culture of design innovation among institutions around such problem domains. *ThinkCycle*[1] is a student-led initiative at Massachusetts Institute of Technology (MIT) that seeks to raise awareness, develop design pedagogy and collaborative tools to address critical design challenges by working closely with universities and organizations worldwide.

Open Collaborative Design: Capturing Design Knowledge in Social Settings?

Most engineering design tools have focused on highly specialized and formal approaches to support collaboration among members of a design team. The complexity of the tools imposes a high barrier for novice or casual users to participate in the design process. Often the focus is primarily on the design artifact, rather than on capturing the evolving rationale and social dialogue in the ongoing design. In multicultural settings, the diverse design perspectives and unintentionally embedded cultural biases are rarely captured. In this article, we propose the need for lightweight online design tools that support gradual problem formulation and design exploration mediated by ongoing dialogue among many distributed participants. Such tools must effortlessly capture design process, rationale and contributions, to make both the outcome and ongoing process useful and relevant to designers, domain experts and stakeholders.

A *design rationale* is an explanation of the reasoning, tacit assumptions, design parameters, operating conditions, dependencies or constraints applied in the creation of an artifact or some part of it [Gruber93]. A design rationale may help justify why specific decisions were made and alternatives chosen in the process of design. It is argued that design rationale is helpful for both the original designers and others in reusing, modifying and maintaining the existing designs. It is also considered useful for designers to communicate and

coordinate within a team over time or negotiate with stakeholders about a design in progress. However, engineers do not have strong incentives to document the rationale in their work due to the added overhead of capture.

Gruber and Russell suggest that existing software tools for engineering design should be extended to provide easy capture or linkage to rationale explanations as a by-product of their usage. [Karsenty96] proposes an iterative approach to capturing design rationale, suggesting that it should be conceived of as an unfinished "document" that evolves over the course of a project through subsequent use of the rationale by others. One system, *Answer Garden* [Ackerman98] allows users to seek answers to commonly asked questions in an information database through sets of diagnostic questions. However, it also allows users to tap into the organization's social network by routing queries on unknown answers to appropriate human experts (via email). This mechanism, hence, provides users and experts a means to grow a body of knowledge on the system over time, through the normal process of posing and answering questions.

Recent trends in the "open source" movement suggest that many benefits can be derived from sharing design knowledge, and allowing an "open" evolution of design based on public peer-review and contributions from diverse participants. Eric Raymond [1997], in his landmark article characterizing the evolution of open source software like Linux, pointed out the importance of a large base of distributed users who help improve the design outcomes much more rapidly but also become indispensable co-developers, if "properly cultivated" during the design process. This "Bazaar view" of software development relies on the fact that each co-developer due to unique background and interests, views the problem with a "slightly different perceptual set and analytical toolkit." This approach is particularly valuable in complex problem domains where expertise cannot easily be found in any one institutional setting, and a wider design exploration of many simultaneous design alternatives and approaches is necessary. With this view, we began to consider how one would create an environment that provides an *Open Collaborative Design* approach, particularly for hardware/product engineering challenges with a distributed community of interest. This framework has begun to emerge in the development of the ThinkCycle initiative.

The ThinkCycle Initiative: A Brief History

In March 2000, several graduate students at the MIT Media Lab proposed an initiative to enable "open source problem solving" among university students everywhere and communities in the developing world. A key part of the initiative was to create an online database of well-posed problems and evolving design solutions. This would be designed to facilitate exchange, raise awareness and harness the expertise of students towards real-world and appropriate design of technology for their communities and the environment.

In the first few months, a proof-of-concept prototype for the online database was developed to serve as a demonstration of the core ideas. However, without an active user community the system lacked the appropriate structure and interface necessary for distributed collaboration. We also recognized that simply building a distributed software platform does not by itself create an environment of design innovation in such problem domains. To test and redesign this platform, we set out to create a novel design course at MIT, focusing on real-world problem solving. We felt that it was necessary to rethink design pedagogy to integrate a culture of collaborative design, multi-disciplinary fields and real-world exposure in engineering courses taught at universities.

In Spring 2001, in consultation with Media Lab professor Mitchel Resnick, we ran a design studio at MIT appropriately titled "Design that Matters,"[2] as a novel experiment to devise a pedagogical approach that would seed challenges and design solutions for the initiative. The studio brought together students from across MIT and Harvard, with notable speakers from around the world to focus on problems like access to clean water, human generated power, bilingual language learning, low-cost health treatment and adaptive eyewear. By nature this studio was developed to test concepts of distributed and collaborative design, where student teams must work with domain experts, NGOs and communities on real-world projects. The students documented the challenges, their ongoing design alternatives as well as the final prototypes.

This studio was also used as the nucleus for developing the ThinkCycle web-based collaboration software. In mid-April 2001 one of the authors, Nitin Sawhney, began development of the current system with iterative feedback from students in the course. An early version of the system was introduced in May for students to document their projects online. Over the year, the system functionality has been extended with many performance improvements to make it a robust and usable collaborative platform.

ThinkCycle: Framework and Design Approach

The ThinkCycle Collaborative platform is designed to provide an evolving online space for discussing, contributing and viewing design challenges, emerging solutions and resources in diverse problem domains. Such domains include Cholera Treatment Devices, Human Power Generation, Emergency Relief Technologies, Rural Community Radio, and Arsenic Remediation. The nature of these domains requires participation from domain experts, stakeholders, designers and the general public. To support sharing of knowledge among such distributed communities, ThinkCycle provides a number of collaborative features on a web-based online platform.

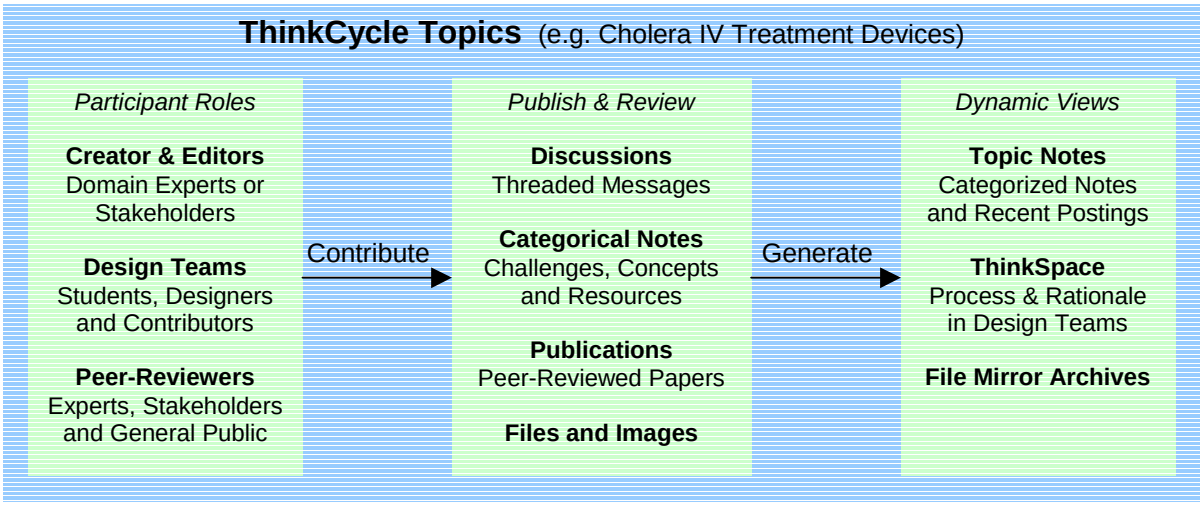

Figure 1: Model for knowledge sharing and collaborative design activities among diverse users.

The system organizes problem domains as "topics" which serve as a shared working space for a community of interest. Topics consist of an online discussion board, shared file-space, categorical notes and publications. NGOs and domain experts typically contribute design challenges and resources posted as notes with online links and relevant images while design teams use the system to post iterative design concepts, technical notes, working files and images from ongoing engineering design. Other participants, including the stakeholders, innovators and the general public review the ongoing design in a topic while posting their own contributions. The topic creators serve as editors (initially) to setup the problem domain, and make suggestions to contributors when needed; however, no formal moderation mechanism is created on the system. When new topics are created, members of the ThinkCycle community are notified by email allowing members to review, join and contribute to it.

Contributions within a topic are categorized as challenges, concepts, resources, technical notes, organizations and so on. These notes consist of short descriptions, along with online links, images and files attached. Users can also add detailed references to relevant books or articles as publications in topics. Publications can include reviews posted by any user. Subscribers to specific topics are notified whenever new content is posted. In addition, when users login to the site, the system displays newly posted items and messages since their last visit. Finally, all content on the system can be easily searched. Together, this set of functionality in an online distributed system, begins to provide a powerful platform for knowledge sharing and collaboration. Iterative refinement of the interface and better personalization and support for group activity should make this a more usable platform for distributed communities.

Case Study on Collaborative Design: The Cholera Treatment Project

We now demonstrate how one design team used the system in the Design that Matters course offered in spring 2001, to archive their work and collaborate on a problem domain related to cholera treatment. This inter-disciplinary design team consisted of three MIT engineering students (including one of the authors, Timothy Prestero), working closely with a local domain expert to explore design approaches for cholera treatment devices. This case study illustrates the design process, emerging design artifacts and outcomes of the project. However, we must note that the ThinkCycle system became available to the design team only in the last half of the design course.

The key design challenge was to develop a novel low-cost IV drip flow control device that would facilitate rapid treatment of patients infected with cholera. Cholera is an acute intestinal infection, which if left untreated can lead to severe dehydration and death. The team began with a basic survey of cholera epidemics and how medical relief organizations currently handle such treatment, particularly in refugee camps where a large number of patients must be treated quickly. In this exploratory problem-formulation phase, the team archived some of the online articles, resources, organizations and established designs as categorical notes on their ThinkCycle topic. Based on their online discussions with domain experts and relevant literature search, the team developed four well-posed challenges for cholera treatment, which were clearly documented on the site.

The team quickly moved into the design phase of the project, experimenting with existing IV drip measurement devices and their own prototype devices. They archived the flow-rate data results of their experiments as documents and excel

spreadsheets on the ThinkCycle file-space, often sharing the uploaded documents with each other and the course instructors in this manner. The team now devised clear design constraints for their proposed devices based on their target users (medical relief assistants in developing countries), which included low cost, accurate flow-rates, ease of operation and simplicity of construction. In a series of group meetings the team came up with a diverse set of 7-10 concept alternatives, followed by concept sketches, detailed design specifications, prototype manufacture and experimental testing of the prototypes. Many of the design artifacts from this process, including sketches, graphs, CAD models and images were archived on ThinkCycle with annotated comments. In some instances, other students in the course and the local domain expert reviewed these artifacts and provided feedback to the team.

The team now found that their nine working design concepts fell in three categories of increasing complexity, and began to evaluate the design constraints for each device based on the criteria proposed earlier. Designs that showed most promise included a modified roller clamp and a rotameter (an instrument for measuring fluid flow rates). These were more extensively refined and tested, while additional documentation regarding their design rationale and advantages/limitations was archived online on a separate website designed by the team. Finally, the team took their design sketches and working prototypes to consult with two doctors at the Massachusetts General Hospital Division of Infectious Diseases. Both doctors had extensive field experience with cholera treatment. The team videotaped and summarized the discussion (both documented on ThinkCycle). The critical feedback from the doctors helped the team understand some of the real world constraints for practitioners and narrow their designs accordingly. They submitted their final paper for peer-review on the ThinkCycle publication library [Prestero01].

How should ThinkCycle be extended to support the team's design activities? There is a need to support lightweight mechanisms for informal contributions and a more coherent view of the unfolding design process. We are currently developing design tools that provide shared spaces for members of individual design teams (within topics) to collaborate towards evolving design concepts. These *ThinkSpaces* serve as informal design notebooks for teams.

ThinkCycle System Implementation

The ThinkCycle online collaboration platform has been developed using an open source framework called the Ars-Digita Community System (ACS). This consists of core services and software modules for managing content, versioning, permissions, user membership, messaging, and session tracking. The main applications for ThinkCycle are developed in the *Tcl* programming language with SQL queries, as packages running on top of the ACS services, including topic and notes categorization, content templates, publication library, peer-reviews and a custom search engine. An Oracle database is used to store and index all data for ThinkCycle. We also maintain a separate development server for prototyping and testing new applications and features. All content files in the Oracle database are extracted four times a day to a separate mirror server, which provides fast text-only access to archived files categorized by topics. The mirror archive can be subsequently placed on distributed servers around the world, for rapid access by universities and local users. This extensive infrastructure allows us to provide a robust and scaleable online platform for a large distributed community of potential users worldwide.

Figure 2: Prototypes of self-calibrating intravenous (IV) drips for cholera treatment.

Related Online Initiatives

Here we outline some non-profit initiatives that utilize an online distributed approach towards knowledge sharing and problem solving. A number of initiatives such as *Distributed.net*[3] and *SETI@home*[4] set out to solve computationally intensive problems by utilizing a distributed network of computers. Many online sites exist for open source software developers such as *SourceForge.net* providing means for tracking and archival of ongoing software projects. One example of open source hardware is the *Simputer* project,[5] a non-profit trust to promote development of low-cost handheld devices for rural settings, initiated by the Indian Institute of Sciences in Bangalore, India. The World Bank recently created the *Development Gateway*,[6] a shared knowledge base of reports and information on international development projects. Finally, a novel initiative for archiving indigenous knowledge is the *Honey Bee Network*,[7] an online database with over 10,000 grassroots innovations collected from farmers in India. Prof. Anil Gupta at the Indian Institute of Management and Sristi, Ahmedabad [Gupta97] initiated it in 1988. ThinkCycle is distinct with its focus on open source collaboration around engineering design innovations for critical problem domains.

Ongoing Work and Open Research Questions

Current initiatives in ThinkCycle are being led by a working group of graduate students and researchers across MIT, with support from faculty in various departments:

- *"Development by design"* Workshops: We organized an

international workshop at MIT in July 2001,[8] to bring together participants from NGOs, industry and academia. The goal was to create a dialogue on design issues for critical challenges in the environment and underprivileged communities. Based on the success of the first workshop, we plan to continue this event in Bangalore, India (2002) and Sao Paulo, Brazil (2003).

- *Challenge Probes with NGOs:* Packages are being mailed to 20-25 non-governmental organizations (NGOs) with questionnaires and disposable cameras, in an effort to seed well posed challenges on ThinkCycle with real-world problems documented by them.
- *Global Design Studio with Universities Worldwide:* A pilot program of design courses is being launched in conjunction with 7-10 universities in Brazil, Costa Rica, Portugal, Kenya and India. They plan to adapt existing design courses or create new ones to incorporate part of the 'Design that Matters' approach and collaborate with local NGOs, industry and design teams at other campuses, using the ThinkCycle platform.

Field study of design interactions on ThinkCycle allows us to consider key questions such as: What formal and informal knowledge do designers and participants freely express in such a publicly accessible online forum? What technical affordances in the system influence active knowledge sharing among local and distributed participants? Under what social and institutional conditions do participants have greater incentive to share design knowledge? What conflicts arise due to intellectual ownership or need for privacy control among participants in diverse institutional settings? In actively collaborating with NGOs in developing countries, what will we learn about the effects of technology and resource disparities on transmitting ideas in general, and the collaborative design process as a whole? These questions should motivate and inform the design of future collaborative tools and pedagogical approaches. Finally, a range of design projects created on ThinkCycle may reveal the distinct conditions and problem domains that more readily support an open collaborative approach for engineering design innovations.

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Raymond, Eric. 1997. The Cathedral and the Bazaar. Article available online. http://www.tuxedo.org/~esr/writings/cathedral-bazaar/cathedral-bazaar/

[1] http://www.thinkcycle.org. The ThinkCycle initiative was devised by Media Lab graduate students Ravi Pappu, Saul Griffith, Nitin Sawhney, Yael Maguire, and Wendy Plesniak. The initiative has expanded with ongoing efforts from Tim Prestero, Ben Vigoda, Jason Taylor, Jesse Kipp and Amy Banzaert. Professors Mitchel Resnick and Bakhtair Mikhak provided guidance in the design studio.
[2] http://www.media.mit.edu/~nitin/thinkcycle/
[3] http://www.distributed.net
[4] http://setiathome.ssl.berkeley.edu
[5] http://www.simputer.org
[6] http://www.developmentgateway.org
[7] http://www.sristi.org/honeybee.html
[8] http://www.thinkcycle.org/dyd